General

Guideline Title

ACR Appropriateness Criteria® seizures and epilepsy.

Bibliographic Source(s)

Luttrull MD, Cornelius RS, Angtuaco EJ, Berger KL, Bykowski J, Holloway K, Kessler MM, Kirsch C, McConnell CT Jr, Mechtler LL, Rosenow JM, Roth CJ, Shetty VS, Slavin K, Waxman AD, Wippold FJ II, Expert Panel on Neurologic Imaging. ACR Appropriateness CriteriaÂ® seizures and epilepsy [online publication]. Reston (VA): American College of Radiology (ACR); 2014. 12 p. [61 references]

Guideline Status

This is the current release of the guideline.

This guideline updates a previous version: Smirniotopoulos JG, Wippold FJ II, Cornelius RS, Angtuaco EJ, Broderick DF, Brown DC, Creasy JL, Davis PC, Garvin CF, Holloway K, McConnell CT Jr, Mechtler LL, Rosenow JM, Seidenwurm DJ, Slavin K, Tobben PJ, Waxman AD, Expert Panel on Neurologic Imaging. ACR Appropriateness Criteria® seizures and epilepsy. [online publication]. Reston (VA): American College of Radiology (ACR); 2011. 10 p. [52 references]

Recommendations

Major Recommendations

ACR Appropriateness Criteria®

Clinical Condition: Seizures and Epilepsy

Variant 1: Medically refractory epilepsy. Surgical candidate or surgical planning.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	8		O
MRI head without and with contrast	8	See statement regarding contrast in the text below under "Anticipated Exceptions."	O
FDG PET head	7	This procedure may be helpful in preoperative planning.	*Relative Radiation Level

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

Radiologic Procedure	Rating	Comments	RRL*
CT head with contrast	6		
MRI functional (fMRI) head without contrast	6	This procedure may be helpful in preoperative planning.	O
MEG	6	This procedure may identify IOZ in nonlesional patients (normal MRI), can provide confirmatory localization information, and may guide placement of iEEG. It may substitute for invasive testing, and may be useful when other tests are discordant.	O
Tc-99m HMPAO SPECT head ictal	5	This procedure may provide confirmatory localization information.	
CT head without contrast	5		
CT head without and with contrast	4		
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 2: New-onset seizure. Unrelated to trauma. Alcohol or drug related.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in the text below under "Anticipated Exceptions."	O
MRI head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	O
CT head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head with contrast	6	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head without and with contrast	3		
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative

Radiologic Procedure	Rating	Comments	RRL*
contrast			
Tc-99m HMPAO SPECT head ictal	2		
FDG-PET/CT head	2		
MEG	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 3: New-onset seizure. Unrelated to trauma. Age 18–40.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	8	In the acute or emergency setting, CT may be the imaging study of choice.	O
MRI head without and with contrast	7	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in the text below under "Anticipated Exceptions."	O
CT head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head with contrast	6	In the acute or emergency setting, CT may be the imaging study of choice.	
Tc-99m HMPAO SPECT head ictal	4		
FDG-PET/CT head	4		
CT head without and with contrast	3		
MRI functional (fMRI) head without contrast	2		O
MEG	2		O

Radiologic Procedure	Rating	Comments	RRL*
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 4: New-onset seizure. Unrelated to trauma. Older than age 40.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding contrast in the text below under "Anticipated Exceptions."	O
MRI head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	O
CT head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head with contrast	6	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head without and with contrast	5		
Tc-99m HMPAO SPECT head ictal	4		
FDG-PET/CT head	4		
MRI functional (fMRI) head without contrast	2		O
MEG	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 5: New-onset seizure. Unrelated to trauma. Focal neurological deficit.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	In the acute or emergency setting, CT may be the imaging study of choice. See statement regarding	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Radiologic Procedure	Rating	Comments	RRL*
		contrast in the text below under "Anticipated Exceptions."	
MRI head without contrast	8	Consider this procedure if intravenous contrast is contraindicated. In the acute or emergency setting, CT may be the imaging study of choice.	O
CT head with contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head without contrast	7	In the acute or emergency setting, CT may be the imaging study of choice.	
CT head without and with contrast	3		
Tc-99m HMPAO SPECT head ictal	3		
FDG-PET/CT head	3		
MRI functional (fMRI) head without contrast	2		O
MEG	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 6: New-onset seizure. Post-traumatic, acute.

Radiologic Procedure	Rating	Comments	RRL*
CT head without contrast	9		
MRI head without and with contrast	8	See statement regarding contrast in the text below under "Anticipated Exceptions."	O
MRI head without contrast	7	Consider this procedure if intravenous contrast is contraindicated.	O
CT head with contrast	5		
CT head without and with contrast	3		*Relative Radiation
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			

Radiologic Procedure	Rating	Comments	RRL*
Tc-99m HMPAO SPECT head ictal	2		
FDG-PET/CT head	2		
MRI functional (fMRI) head without contrast	2		O
MEG	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 7: New-onset seizure. Post-traumatic. Subacute or chronic.

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	8	Consider this procedure if intravenous contrast is contraindicated.	O
MRI head without and with contrast	8	See statement regarding contrast in the text below under "Anticipated Exceptions."	O
CT head without contrast	7		
CT head with contrast	6		
FDG-PET/CT head	5		
MRI functional (fMRI) head without contrast	4		O
CT head without and with contrast	3		
Tc-99m HMPAO SPECT head ictal	2		
MEG	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative

Radiological Procedure	Rating	Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate	Relative Radiation Level*

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Summary of Literature Review

Introduction/Background

A seizure is a finite event of altered cerebral function because of excessive and abnormal electrical discharges of the brain cells. Epilepsy is a chronic condition predisposing a person to recurrent seizures. Epilepsy is common, affecting approximately 2 million people in the United States at any one time with a world-wide age-adjusted incidence of 16-111/100,000 people per year. It has been estimated that about 7% to 8% of the population experiences at least one epileptic seizure during their lifetimes. The basic mechanism of epileptic seizures has not been fully elucidated.

The classification of epileptic seizures by the International League Against Epilepsy was last revised in 2010. The classification is important because etiologic diagnosis, appropriate treatment, and accurate prognostication all depend on the correct identification of seizures and epilepsy. There are two main types of seizures: generalized and focal. The separation of "focal" from "generalized" seizures is a useful construct—even if this separation is not truly distinct. Focal seizures are those arising within networks of a single cerebral hemisphere and may remain localized or subsequently become more widely distributed. Generalized seizures rapidly affect both hemispheres as well as both sides of the body—even when caused by a "focal" lesion. Generalized seizures are further subdivided into tonic-clonic, absence, myoclonic, clonic, tonic, and atonic. The older classification terms for focal seizures ("simple partial," "complex partial," and "partial") have been supplanted, and these distinctions have been removed. Certain types of seizure disorders are likely to be associated with structural brain lesions, including tumors, infection, infarction, traumatic brain injury, vascular malformations, developmental abnormalities, and seizure-associated brain pathology. Hence, knowledge of seizure types helps to determine whether neuroimaging is clinically indicated and what type of study is appropriate.

Overview of Imaging Modalities

Imaging modalities used in the evaluation of seizures can be subdivided into those evaluating brain structure, metabolism, perfusion, and electrical activity. Magnetic resonance imaging (MRI) and computed tomography (CT) are the primary modalities used in the evaluation of structural lesions known to induce seizures. Clinical positron emission tomography (PET) with fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG) provides a measure of glucose uptake and thus a measure of metabolism. A seizure focus will typically manifest as a focus of hypometabolism on interictal (between episodes of seizure activity) PET examinations. Additional PET tracers have been developed targeting specific brain receptors affected during seizures, including α-[11C]methyl-L-tryptophan in tuberous sclerosis, which are promising advancements in the evaluation and management of epilepsy. Both bolus MRI (MR perfusion) and single-photon emission computed tomography (SPECT) that uses perfusion agents such as 99mTc-HMPAO or 99mTc-Neurolite, provide an assessment of regional cerebral blood flow rather than brain metabolism. A seizure focus will typically be seen as an area of hypoperfusion on interictal examinations and will demonstrate increased activity on *ictal* examinations. Only electroencephalogram (EEG) (using either scalp electrodes or intracranial electrodes [iEEG]) and magnetoencephalography (MEG) directly measure the brain's electrical activity. As such, they could or should be the gold standard for seizure localization. Functional MRI (fMRI) techniques include phosphorus and proton spectroscopy (MRS), MR perfusion, and blood-oxygen-level dependent (BOLD) activation. The widespread application of most of these techniques in clinical practice depends on the widespread availability of high-performance MR images capable of performing fast echo-planar pulse sequences (EPIs), as well as substantial data postprocessing capabilities.

MRS is a set of noninvasive techniques for *in vivo* chemical analysis of the brain, some of which can be performed on standard-performance clinical MR units. Widely available proton and phosphorus single-voxel techniques have consistently demonstrated metabolite changes in the epileptogenic region of the brain. For example, typical metabolite changes on proton spectroscopy include reduced N-acetylaspartate and elevated lactate in the region of the seizure focus.

Variant 1: Medically Refractory Epilepsy; Surgical Candidate or Surgical Planning

Computed Tomography/Magnetic Resonance Imaging

Although the imaging evaluation of epilepsy was greatly advanced by the clinical introduction of CT in the early 1970s, because of its superior soft-tissue contrast, multiplanar imaging capability, and lack of beam hardening artifacts, virtually all the substrates of epilepsy are visualized with greater sensitivity and accuracy by MRI. As a result, MRI has become the modality of choice for high-resolution structural imaging in epilepsy. Routine evaluation techniques of all clinically available scanner field strengths may be sufficient for determination of mass lesions. However, optimized protocols for scans obtained on high-field (>1.5 T) scanners may be necessary for evaluating focal seizures ("partial complex epilepsy"). These

patients require scrutiny of the hippocampus and temporal lobe for atrophy and subtle signal alteration, as well as for detecting certain structural abnormalities such as cortical dysplasias, hamartomas, and other developmental abnormalities. Anatomic imaging identifies a focal abnormality in up to 54% of patients with focal seizures excluding atrophy and nonspecific white-matter lesions. Intravenous contrast can be a useful addition to the MR examination, particularly if there is a clinical suspicion of infection, tumor, inflammatory lesion, or vascular pathology. MR volumetric and relaxometry techniques have been shown to increase the detection of mesial temporal sclerosis. With the widespread clinical availability of high-performance MRI systems, a comprehensive MRI examination, with functional techniques providing additional information, adding corroborative information, and improving overall accuracy, may in the future be of even greater value in diagnosing epilepsy.

Functional Studies

Although the data provided by MRI are essential in the presurgical evaluation of patients with medically refractory epilepsy, structurally detectable abnormalities are absent in many patients. In these patients, functional studies provide useful information on the location of the seizure focus. Functional imaging techniques, including PET, SPECT, magnetic source imaging (MSI), and fMRI, have contributed to the presurgical evaluation of patients with epilepsy.

The utility of isolated interictal cerebral perfusion assessment in patients without anatomic imaging abnormality has been shown to be limited due to low sensitivity and its false-positive rate. The relative utility of interictal FDG-PET, ictal SPECT, and MRI at detecting seizure foci based on EEG criteria was evaluated in a meta-analysis in 1994. Ictal SPECT was 90% sensitive and 77% specific at detecting temporal lobe epilepsy (TLE) and was 81% sensitive and 93% specific at detecting extratemporal epilepsy. It was the most sensitive test at detecting seizure foci regardless of location. Interictal FDG-PET was found to be 84% sensitive and 86% specific at detecting TLE and 33% sensitive and 95% specific at detecting extratemporal epilepsy. By comparison, structural imaging using a variety of MR field strengths and techniques yielded a sensitivity of 55% and a specificity of 78% in TLE and 43% sensitivity and 95% specificity in extratemporal epilepsy.

The use of subtraction ictal SPECT coregistered on MRI and image-guided surgery datasets is proving to be more useful than interictal perfusion imaging alone. A recent study comparing the performance of subtraction ictal SPECT and interictal PET at detecting seizure foci found on intracranial EEG monitoring demonstrated ictal/interictal subtraction imaging to be the more sensitive examination. However, both modalities revealed complementary information. Injection of the blood flow agent within 90 seconds of seizure onset does, however, appear to be required to demonstrate the expected localized increase in cerebral perfusion on ictal SPECT. The use of ictal perfusion techniques in epilepsy is therefore often limited to specialized centers because of the technological and staffing challenge of injecting EEG-monitored patients within 90 seconds of seizure onset.

Out of the fMRI techniques available, BOLD imaging appears to be the most useful for preoperative planning. In a prospective study of 53 patients with seizure, fMRI results altered patient and family counseling in 58% of patients, prevented further studies including Wada tests in 63%, altered intraoperative mapping plans in 52%, changed surgical plans in 42%, prevented 2-stage surgery in 8%, and altered the extent of surgical resection in 7% due to identification of nearby eloquent areas of brain.

MRS or chemical shift imaging (CSI) allows simultaneous acquisition of spectra from all brain regions. The pictorial display of MRS information facilitates comparison of the epileptogenic zone with the remainder of the brain and provides localizing information. Studies suggest that both proton and phosphorus MRS may be useful adjunctive presurgical tests for localizing seizure foci in patients with partial epilepsy, particularly in difficult cases, potentially reducing the need for intracranial-depth electrode EEG recordings, and in those with extratemporal seizure foci. However, CSI is not yet widely available in clinical practice, and more study is needed to clarify its use in clinical practice.

In terms of outcome, being "seizure free" is an appropriate metric. Both EEG and MEG offer significantly higher temporal resolution (ms), as compared with interictal PET, ictal SPECT, and fMRI, which are poor by comparison (sec-min). Recent improvements in MEG technology—with advanced electronics and 100–300 or more channels of whole-head magnetometers—now allow complete brain coverage and overlay of source information on magnetic source images (MSIs). Recent articles in the radiology literature describe both the techniques and the advantages of including MEG in the preoperative evaluation of patients with intractable or medically refractory seizures. The MEG images are often superimposed on high-resolution MRIs. MEG is not a "frontline" tool for evaluation of epilepsy. A literature review supports some utility for MEG in the subset of patients who: a) are surgical candidates for resection; b) do not have a lesion identified on scalp EEG and MRI or have multiple potential seizure foci; or c) are candidates for invasive monitoring (iEEG).

MEG is thus complementary to EEG and may provide confirmatory information for the ictal onset zone (IOZ) localization for potential lesions seen on MRI. MEG provides better spatial resolution (2-3 mm) as compared to EEG (7-10 mm). MEG can also guide the placement of iEEG grids, and in certain patients it may help distinguish among multiple potential seizure foci.

The use and utility of MEG are growing, but are by no means settled. Many of the strong advocates for MEG have become familiar with the technique from their own research and have made their own contributions to this literature. It might well be emphasized that MEG has the most value in the hands of experienced users in epilepsy referral centers.

Variants 2–7: New-onset Seizures

Computed Tomography/Magnetic Resonance Imaging

New-onset seizures can be divided into those that are suspected to have an acute preceding structural or metabolic cause such as trauma, tumor, or infection (formerly called provoked or acute symptomatic seizures) and those lacking a suspected, acute triggering condition (formerly called unprovoked, cryptogenic, idiopathic, or remote symptomatic seizures). In both categories of new-onset seizures, structural imaging plays an important role in diagnosing treatable lesions and in determining whether or not antiepileptic drug therapy should be initiated. In a review of 7 class II studies using either CT or MRI in the evaluation of new-onset, unprovoked seizures, significant abnormalities were found in an average of 10% patients that altered medical management. Studies have found that patients with focal neurologic deficits, head trauma, focal onset of seizure, history of human immunodeficiency virus (HIV) or malignancy, children <6 months of age, and the elderly are at higher risk of having abnormalities on imaging or have findings on CT that significantly altered management in the emergent setting. MRI is preferred over CT in the assessment of a first seizure due to its increased sensitivity at detecting intracranial abnormalities. In 2007, an expert panel on the Quality Indicators for Epilepsy Treatment (QUIET) study identified a list of 24 evidence-based measures for the evaluation and treatment of patients with epilepsy. Evaluation of new-onset seizure was the first quality indicator listed by the panel, and orders for both EEG and neuroimaging with MRI or CT (MRI preferred) or, alternatively, a referral to a higher level of epilepsy specialty care were included among its elements. In urgent and emergency room settings, CT is generally accepted as the imaging study of choice for patients presenting with new-onset seizure. Addition of intravenous contrast to either an MRI or CT examination is useful in the assessment for underlying tumor, infection, inflammatory lesion, or vascular pathology; its potential added value will depend on clinical history and patient demographics.

Functional Studies

Although the roles of functional imaging with interictal PET, ictal SPECT, fMRI, and MEG are scientifically established in the presurgical evaluation of patients with medically refractory epilepsy, their utility in the evaluation of patients with new-onset seizure appears limited. No articles concerning functional imaging techniques and their role in the clinical diagnosis, management, or outcomes of new-onset seizure patients were identified in the recent literature review. However, in certain circumstances, functional imaging techniques may provide additional information useful in establishing the diagnosis of acute epileptogenic lesions associated with focal neurologic deficits such as infarcts, intracranial abscess and infection, primary central nervous system (CNS) neoplasm, metastasis, and lymphoma (see the National Guideline Clearinghouse [NGC] summary of the American College of Radiology [ACR] Appropriateness Criteria® focal neurologic deficit).

Variant 2: New-onset Seizure, Unrelated to Trauma. Alcohol or Drug Related

Patients presenting with a new-onset seizure that is suspected to be drug or alcohol related should undergo neuroimaging with either MRI or CT. CT is generally accepted as the test of choice to be performed in the emergency setting. If imaging is deferred on an outpatient basis, MRI is preferred over CT due to its increased sensitivity at detecting intracranial abnormalities. In a study of 259 patients presenting with a first, alcohol-related, generalized convulsive seizure, 6.2% were found to have intracranial lesions. Clinical management was changed based on the CT result in 3.9% of the patients, and there was no significant correlation between abnormal head CT results and level of consciousness or focal neurologic abnormalities on exam.

Variant 3: New-onset Seizure, Unrelated to Trauma. Age 18-40

Patients presenting with new-onset seizures between the ages of 18 and 40 who lack a history of preceding trauma should undergo neuroimaging with either MRI or CT (MRI preferred). CT may be more appropriate in the emergency setting. Diagnoses of underlying abnormalities found on imaging in this age group can often be made on noncontrast MR examinations and include intracranial trauma and arteriovenous malformations. Tumors are less frequent. However, a contrast-enhanced examination should still be performed if intracranial infection, tumor, inflammatory lesion, or vascular pathology are suspected.

Variant 4: New-onset Seizure, Unrelated to Trauma. Older Than Age 40

Patients presenting with new-onset seizures over age 40 who lack a history of trauma should undergo neuroimaging with either MRI or CT (MRI preferred). CT may be more appropriate in the emergency setting. Patients in this age group have a higher association with abnormal findings on MRI, including an increased frequency of underlying stroke or tumor. Therefore, contrast-enhanced examinations are more appropriate in this population.

Variant 5: New-onset seizure, Unrelated to Trauma. Focal Neurological Deficit

Patients presenting with new-onset seizures associated with a focal neurological deficit and who lack a history of preceding trauma should undergo neuroimaging with either MRI or CT (MRI preferred). CT may be more appropriate in the emergency setting. The presence of a focal neurological

deficit in the setting of a new-onset seizure has been found to be associated with a higher risk of subsequent abnormalities on neuroimaging. In a prospective study of 119 adult patients presenting to an urban emergency department with first seizure, a focal neurological defect was found to be 50% sensitive and 89% specific in the identification of patients with a focal lesion on CT (odds ratio 4.9 [95% confidence interval, 1.7–13.7]). Etiology of seizure for those with focal neurologic defects was primary neoplasm (25%), metastasis (25%), intracranial hemorrhage (20%), infarct (20%), and toxoplasmosis (10%). Functional imaging techniques may provide additional useful information in establishing the diagnosis (see the NGC summary of the ACR Appropriateness Criteria® focal neurologic deficit).

Variant 6: New-onset Seizure. Post-traumatic, Acute

The imaging test of choice for patients presenting with new-onset, post-traumatic seizures in the acute setting is a noncontrast head CT due to the high association of acute intracranial hemorrhage in this patient population. MRI is also useful in evaluating for acute traumatic brain injury (see the NGC summary of the ACR Appropriateness Criteria® head trauma). In a series of 100 adult patients who presented with post-traumatic seizure within one week of minor closed head injury, 41% were found to have intracranial hemorrhage, and 7% underwent craniotomy for evacuation of hematoma associated with mass effect and midline shift. Penetrating injuries, skull fractures, or frontal sinus fractures may become complicated by significant intracranial infections. Therefore, contrast-enhanced examinations may be useful in the appropriate clinical setting.

Variant 7: New-onset Seizure. Post-traumatic. Subacute or Chronic

Patients who develop a new-onset seizure following nonacute head trauma (i.e., greater than one week in the past) may be experiencing a "late-onset" post-traumatic seizure. MRI is the preferred imaging modality in the assessment of traumatic brain injury beyond the acute phase due to its higher sensitivity at detecting hemosiderin deposition from prior intracranial hemorrhage on T2 gradient or susceptibility-weighted sequences (see the NGC summary of the ACR Appropriateness Criteria® head trauma). CT may be more appropriate in the emergency setting. Morphologic assessment of gliomesenchymal lesions on MRI as well as more advanced MRI applications such as diffusion tensor imaging may prove to be useful in predicting the development of late-onset post-traumatic epilepsy, although more research is needed.

Summary

- This document addresses several subsets of patients with seizures and epilepsy.
- MRI is the imaging test of choice for the evaluation of medically refractory epilepsy patients who are surgical candidates.
- Some medically refractory epilepsy patients may have more than one lesion and/or discordance between electrical findings on EEG and imaging localization. In these circumstances interictal FDG-PET, MEG, and ictal SPECT imaging may help define the most likely ictal onset zone. fMRI may be most useful in surgical planning to avoid damage to critical structures.
- Patients presenting with new-onset seizures should undergo imaging with either MRI or CT, with MRI being the preferred modality. CT may be more appropriate in the emergency setting.
- CT is the imaging test of choice in the evaluation of patients presenting with seizures following acute trauma. MRI can be useful in the evaluation of post-traumatic seizures in both the acute and, particularly, the nonacute setting.
- Addition of intravenous contrast to either an MRI or CT examination is useful in the assessment for underlying tumor, infection, inflammatory lesion, or vascular pathology.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (i.e., <30 mL/min/1.73 m^2), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73 m^2. For more information, please see the ACR Manual on Contrast Media (see the "Availability of Companion Documents" field).

Abbreviations

- CT, computed tomography
- FDG-PET, fluorine-18-2-fluoro-2-deoxy-D-glucose-positron emission tomography
- fMRI, functional magnetic resonance imaging
- HMPAO, hexamethyl propylene amine oxime
- iEEG, intracranial electroencephalography
- IOZ, intracranial onset zone

- MEG, magnetoencephalography
- MRI, magnetic resonance imaging
- SPECT, single-photon emission computed tomography
- Tc-99m, technetium-99 metastable

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☐	<0.1 mSv	<0.03 mSv
☐☐	0.1-1 mSv	0.03-0.3 mSv
☐☐☐	1-10 mSv	0.3-3 mSv
☐☐☐☐	10-30 mSv	3-10 mSv
☐☐☐☐☐	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

Clinical Algorithm(s)

Algorithms were not developed from criteria guidelines.

Scope

Disease/Condition(s)

Seizures and epilepsy

Guideline Category

Diagnosis

Evaluation

Clinical Specialty

Emergency Medicine

Family Practice

Internal Medicine

Neurology

Nuclear Medicine

Radiology

Intended Users

Health Plans

Hospitals

Managed Care Organizations

Physicians

Utilization Management

Guideline Objective(s)

To evaluate the appropriateness of initial radiologic examinations for patients with seizures and epilepsy

Target Population

Patients with seizures and epilepsy

Interventions and Practices Considered

1. Magnetic resonance imaging (MRI) head
    - Without contrast
    - Without and with contrast
2. Functional MRI (fMRI) head without contrast
3. Computed tomography (CT) head
    - With contrast
    - Without contrast
    - Without and with contrast
4. Technetium-99 metastable (Tc-99m) hexamethyl propylene amine oxime (HMPAO) single-photon emission computed tomography (SPECT) head
5. Fluorine-18-2-fluoro-2-deoxy-D-glucose-positron emission tomography (FDG-PET)/CT head
6. Magnetoencephalography (MEG)

Major Outcomes Considered

- Utility of radiologic examinations in differential diagnosis
- Sensitivity, specificity, and accuracy of radiologic examinations
- Predictive and prognostic value of radiologic examinations

Methodology

Methods Used to Collect/Select the Evidence

Searches of Electronic Databases

Description of Methods Used to Collect/Select the Evidence

Literature Search Procedure

Staff search in PubMed only for peer reviewed medical literature for routine searches. Any article or guideline may be used by the author in the narrative but those materials may have been identified outside of the routine literature search process.

The Medline literature search is based on keywords provided by the topic author. The two general classes of keywords are those related to the condition (e.g., ankle pain, fever) and those that describe the diagnostic or therapeutic intervention of interest (e.g., mammography, MRI).

The search terms and parameters are manipulated to produce the most relevant, current evidence to address the American College of Radiology Appropriateness Criteria (ACR AC) topic being reviewed or developed. Combining the clinical conditions and diagnostic modalities or therapeutic procedures narrows the search to be relevant to the topic. Exploding the term "diagnostic imaging" captures relevant results for diagnostic topics.

The following criteria/limits are used in the searches.

1. Articles that have abstracts available and are concerned with humans.
2. Restrict the search to the year prior to the last topic update or in some cases the author of the topic may specify which year range to use in the search. For new topics, the year range is restricted to the last 10 years unless the topic author provides other instructions.
3. May restrict the search to Adults only or Pediatrics only.
4. Articles consisting of only summaries or case reports are often excluded from final results.

The search strategy may be revised to improve the output as needed.

Number of Source Documents

The total number of source documents identified as the result of the literature search is not known.

Methods Used to Assess the Quality and Strength of the Evidence

Weighting According to a Rating Scheme (Scheme Given)

Rating Scheme for the Strength of the Evidence

Study Quality Category Definitions

Category 1 - The study is well-designed and accounts for common biases.

Category 2 - The study is moderately well-designed and accounts for most common biases.

Category 3 - There are important study design limitations.

Category 4 - The study is not useful as primary evidence. The article may not be a clinical study or the study design is invalid, or conclusions are based on expert consensus. For example:

a. The study does not meet the criteria for or is not a hypothesis-based clinical study (e.g., a book chapter or case report or case series description).
b. The study may synthesize and draw conclusions about several studies such as a literature review article or book chapter but is not primary evidence.
c. The study is an expert opinion or consensus document.

Methods Used to Analyze the Evidence

Review of Published Meta-Analyses

Systematic Review with Evidence Tables

Description of the Methods Used to Analyze the Evidence

The topic author drafts or revises the narrative text summarizing the evidence found in the literature. American College of Radiology (ACR) staff draft an evidence table based on the analysis of the selected literature. These tables rate the strength of the evidence (study quality) for each article included in the narrative text.

The expert panel reviews the narrative text, evidence table, and the supporting literature for each of the topic-variant combinations and assigns an appropriateness rating for each procedure listed in the table. Each individual panel member assigns a rating based on his/her interpretation of the available evidence.

More information about the evidence table development process can be found in the ACR Appropriateness Criteria® Evidence Table Development document (see the "Availability of Companion Documents" field).

Methods Used to Formulate the Recommendations

Expert Consensus (Delphi)

Description of Methods Used to Formulate the Recommendations

Rating Appropriateness

The appropriateness ratings for each of the procedures included in the Appropriateness Criteria topics are determined using a modified Delphi methodology. A series of surveys are conducted to elicit each panelist's expert interpretation of the evidence, based on the available data, regarding the appropriateness of an imaging or therapeutic procedure for a specific clinical scenario. American College of Radiology (ACR) staff distributes surveys to the panelists along with the evidence table and narrative. Each panelist interprets the available evidence and rates each procedure. The surveys are completed by panelists without consulting other panelists. The appropriateness rating scale is an ordinal scale that uses integers from 1 to 9 grouped into three categories: 1, 2, or 3 are in the category "usually not appropriate"; 4, 5, or 6 are in the category "may be appropriate"; and 7, 8, or 9 are in the category "usually appropriate." Each panel member assigns one rating for each procedure for a clinical scenario. The ratings assigned by each panel member are presented in a table displaying the frequency distribution of the ratings without identifying which members provided any particular rating.

If consensus is reached, the median rating is assigned as the panel's final recommendation/rating. Consensus is defined as eighty percent (80%) agreement within a rating category. A maximum of three rounds may be conducted to reach consensus. Consensus among the panel members must be achieved to determine the final rating for each procedure.

If consensus is not reached, the panel is convened by conference call. The strengths and weaknesses of each imaging procedure that has not reached consensus are discussed and a final rating is proposed. If the panelists on the call agree, the rating is proposed as the panel's consensus. The document is circulated to all the panelists to make the final determination. If consensus cannot be reached on the call or when the document is circulated, "No consensus" appears in the rating column and the reasons for this decision are added to the comment sections.

This modified Delphi method enables each panelist to express individual interpretations of the evidence and his or her expert opinion without excessive influence from fellow panelists in a simple, standardized and economical process. A more detailed explanation of the complete process can be found in additional methodology documents found on the ACR Web site (see also the "Availability of Companion Documents" field).

Rating Scheme for the Strength of the Recommendations

Not applicable

Cost Analysis

A formal cost analysis was not performed and published cost analyses were not reviewed.

Method of Guideline Validation

Internal Peer Review

Description of Method of Guideline Validation

Criteria developed by the Expert Panels are reviewed by the American College of Radiology (ACR) Committee on Appropriateness Criteria.

Evidence Supporting the Recommendations

Type of Evidence Supporting the Recommendations

The recommendations are based on analysis of the current literature and expert panel consensus.

Benefits/Harms of Implementing the Guideline Recommendations

Potential Benefits

Selection of appropriate radiologic imaging procedures for evaluation of patients with seizures and epilepsy

Potential Harms

Gadolinium-Based Contrast Agents

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (i.e., <30 mL/min/1.73 m^2), and almost never in other patients. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73 m^2. For more information, please see the American College of Radiology (ACR) Manual on Contrast Media (see the "Availability of Companion Documents" field).

Relative Radiation Level

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document (see the "Availability of Companion Documents" field).

Qualifying Statements

Qualifying Statements

The American College of Radiology (ACR) Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and

severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the U.S. Food and Drug Administration (FDA) have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Implementation of the Guideline

Description of Implementation Strategy

An implementation strategy was not provided.

Institute of Medicine (IOM) National Healthcare Quality Report Categories

IOM Care Need

Living with Illness

IOM Domain

Effectiveness

Identifying Information and Availability

Bibliographic Source(s)

Luttrull MD, Cornelius RS, Angtuaco EJ, Berger KL, Bykowski J, Holloway K, Kessler MM, Kirsch C, McConnell CT Jr, Mechtler LL, Rosenow JM, Roth CJ, Shetty VS, Slavin K, Waxman AD, Wippold FJ II, Expert Panel on Neurologic Imaging. ACR Appropriateness CriteriaÂ® seizures and epilepsy [online publication]. Reston (VA): American College of Radiology (ACR); 2014. 12 p. [61 references]

Adaptation

Not applicable: The guideline was not adapted from another source.

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1996 (revised 2014)

Guideline Developer(s)

American College of Radiology - Medical Specialty Society

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Guideline Committee

Committee on Appropriateness Criteria, Expert Panel on Neurologic Imaging

Composition of Group That Authored the Guideline

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Financial Disclosures/Conflicts of Interest

Not stated

Guideline Status

This is the current release of the guideline.

This guideline updates a previous version: Smirniotopoulos JG, Wippold FJ II, Cornelius RS, Angtuaco EJ, Broderick DF, Brown DC, Creasy JL, Davis PC, Garvin CF, Holloway K, McConnell CT Jr, Mechtler LL, Rosenow JM, Seidenwurm DJ, Slavin K, Tobben PJ, Waxman AD, Expert Panel on Neurologic Imaging. ACR Appropriateness Criteria® seizures and epilepsy. [online publication]. Reston (VA): American College of Radiology (ACR); 2011. 10 p. [52 references]

Guideline Availability

Electronic copies: Available from the American College of Radiology (ACR) Web site.

Print copies: Available from the American College of Radiology, 1891 Preston White Drive, Reston, VA 20191. Telephone: (703) 648-8900.

Availability of Companion Documents

The following are available:

- ACR Appropriateness Criteria®. Overview. Reston (VA): American College of Radiology; 2013 Nov. 3 p. Electronic copies: Available from the American College of Radiology (ACR) Web site.
- ACR Appropriateness Criteria®. Literature search process. Reston (VA): American College of Radiology; 2013 Apr. 1 p. Electronic copies: Available from the ACR Web site.
- ACR Appropriateness Criteria®. Evidence table development – diagnostic studies. Reston (VA): American College of Radiology; 2013 Nov. 3 p. Electronic copies: Available from the ACR Web site.
- ACR Appropriateness Criteria®. Radiation dose assessment introduction. Reston (VA): American College of Radiology; 2103 Nov. 3 p. Electronic copies: Available from the ACR Web site.
- ACR Appropriateness Criteria®. Manual on contrast media. Reston (VA): American College of Radiology; 90 p. Electronic copies: Available from the ACR Web site.
- ACR Appropriateness Criteria®. Procedure information. Reston (VA): American College of Radiology; 1 p. Electronic copies: Available from the ACR Web site.
- ACR Appropriateness Criteria® seizures and epilepsy. Evidence table. Reston (VA): American College of Radiology; 2014. 22 p.

Electronic copies: Available from the ACR Web site .

Patient Resources

None available

NGC Status

This NGC summary was completed by ECRI on July 31, 2001. The information was verified by the guideline developer as of August 24, 2001. This summary was updated by ECRI Institute on April 26, 2007, July 8, 2011, and August 1, 2014.

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